MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EEE1016 – ELECTRONICS I

(All Sections / Groups)

23 OCTOBER 2019
2.30 p.m - 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **9** pages including the cover page and Appendix. There are **FOUR** questions in this paper.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of marks for each question is given.

3. Some useful formulae are given in the Appendix section.

4. Please write all your answers in the Answer Booklet provided.

Question 1

(a) N-type extrinsic semiconductor materials are produced from the controlled addition of pentavalent impurities to the intrinsic (pure) semiconductor. Sketch the energy band diagram for the N-type semiconductor. Next, explain how the majority carriers are produced in the N-type material. [5 marks]

(b) For a sample of intrinsic Silicon (Si), the electron and hole mobilities are $\mu_n = 1350$ cm^2/V-s and $\mu_p = 450$ cm^2/V-s, respectively. The resistivity of the pure Si is 80 Ω-cm. The Si material is doped to the extent of 1×10^{14} donor atoms/cm^3 and 4×10^{13} acceptor atoms/cm^3.

(i) Find the intrinsic carrier concentration of the Si. [3 marks]

(ii) Determine the electron and hole concentrations of the extrinsic Si material. [6 marks]

(iii) Calculate the drift current density of the extrinsic Si for an applied electric field of $E = 100$ V/cm. [2 marks]

(c) Figure Q1(c) depicts a diode circuit with a supply voltage $V_S = 24$ V, current limiting resistor $R_S = 220$ Ω, silicon (Si) p-n junction diodes (D1, D2), zener diode (D3), and load resistor $R_L = 1$ kΩ. The p-n junction diodes have cut-in voltage $V_\gamma = 0.7$ V, and forward diode resistance $R_f = 25$ Ω. The zener voltage of diode D3 is $V_Z = 4.7$ V.

(i) Draw the piecewise-linear diode equivalent circuit. [2 marks]

(ii) Find the current I. [3 marks]

(iii) Calculate the voltage drop across the resistor R_L. [2 marks]

(iv) If V_S is increased to 36 V, determine the new value of R_S such that the current I remains the same. [2 marks]

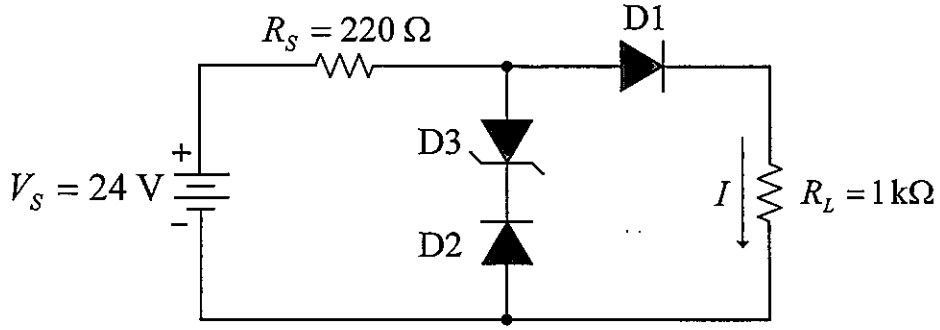

Figure Q1(c)

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Question 2

(a) Figure Q2(a)(i) and Figure Q2(a)(ii) show the rectifier circuits capable of producing a single-polarity output over the load resistor from a sinusoidal input voltage signal, $V_i = V_m \sin(2\pi ft)$ with V_m = 15.0 V and operating frequency, f = 60 Hz. Given that the load resistance R_L is 500 Ω, capacitor C = 470 μF, and all diodes in the circuits have cut-in voltage, V_γ = 0.7 V, $R_r = \infty$, and R_f is negligible.

(i) Name the rectifier circuits of Figure Q2(a)(i) and Figure Q2(a)(ii). [1 mark]

(ii) Draw the output voltage waveform of these TWO rectifiers. [4 marks]

(iii) Determine the average output voltage, $V_{o(av)}$ of these TWO rectifier. [3 marks]

(iv) Determine the ripple voltage, $V_{r(pp)}$ of these TWO rectifier. [3 marks]

(v) Give TWO disadvantages of the rectifier in Figure Q2(a)(i) as compared to the rectifier in Figure Q2(a)(ii). [2 marks]

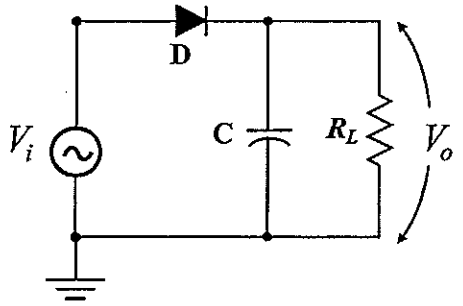

Figure Q2(a)(i)

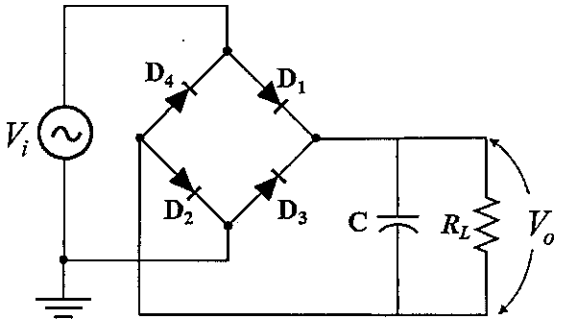

Figure Q2(a)(ii)

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Question 2

(b) Figure Q2(b) shows a clipper circuit designed to limit the output voltage, V_o. R is a current limiting resistance. The input voltage signal is $V_i = V_m\sin(2\pi ft)$ with V_m = 3.0 V and f = 60 Hz.

(i) Determine the maximum and minimum output voltages and draw the output voltage waveform if D_1, D_2 and D_3 are Silicon (Si) diodes with cut-in voltage V_γ = 0.7 V. [6 marks]

(ii) Draw the output voltage waveform if D_2 and D_3 are replaced with Germanium (Ge) diodes with cut-in voltage V_γ = 0.3 V. In your diagram, indicate the maximum and minimum output voltages. [3 marks]

(iii) Draw a clipper circuit using Si diodes to limit the output voltage at both ±1.4V. [3 marks]

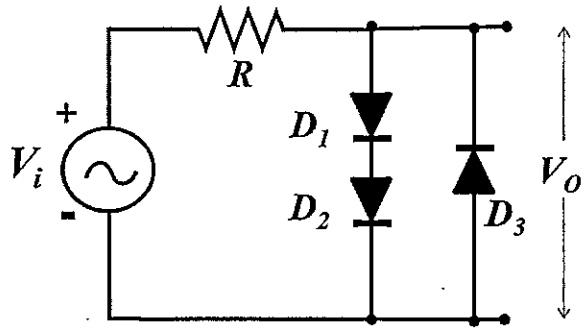

Figure Q2(b)

Question 3

(a) The transistor biasing model is shown in Table Q3(a). Depending on the transistor biasing across each of the junctions, different modes of operation are obtained, that are saturation, active, inverted and cut-off. Fill up the blanks of biasing polarity for E-B junction and C-B junctions. [4 marks]

Biasing Mode	Biasing Polarity (E-B Junction)	Biasing Polarity (C-B Junction)
Saturation		
Active		
Cutoff		
Inverted		

Table Q3(a)

Continued...

Question 3

(b) Figure Q3(b) shows and indicates the current flow (a), (b), (c), and (d) in semiconductor sample. What are the FOUR possibilities that electrons flow from Emitter to Base in NPN transistor? [4 marks]

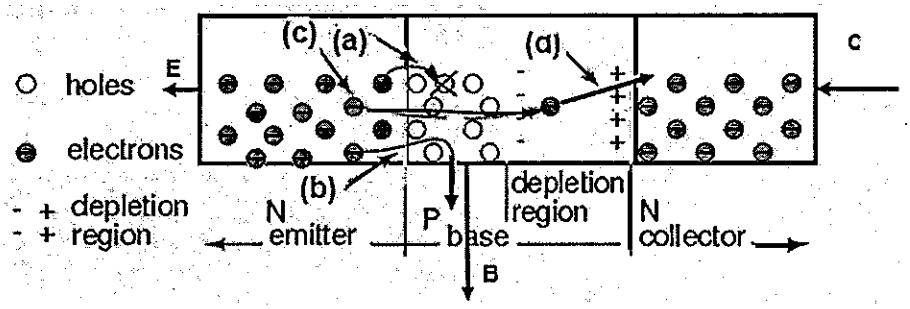

Figure Q3(b)

(c) The emitter-stabilized bias BJT circuit is shown in Figure Q3(c). Given values: R_B=470kΩ, R_C=1kΩ, R_E=500Ω V_{CC}=15V, assume that β is 100 and V_{BE} is 0.7 V. Determine the following:

(i) The base current I_B. [4 marks]

(ii) The collector current (I_{CQ}) at Q-point and emitter current (I_E). [4 marks]

(iii) The output voltage (V_{CEQ}) at Q-point. [4 marks]

(iv) Draw the common-emitter (C-E) output characteristic. Indicate clearly the Q-point, DC load line, $I_{C(sat)}$ and $V_{CE(cutoff)}$. [5 marks]

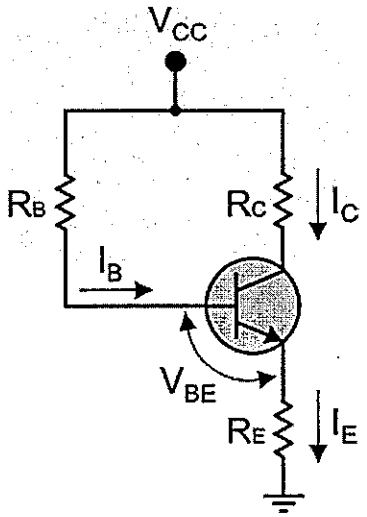

Figure Q3(c)

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Question 4

(a) The two-port device transistor modeling is shown in Figure Q4(a). List the FOUR h-parameters. [4 marks]

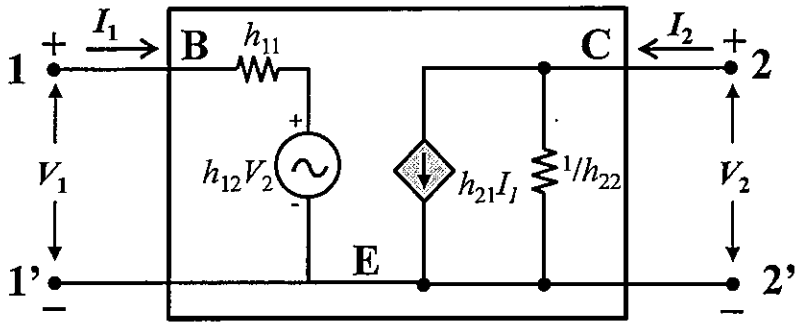

Figure Q4(a)

(b) The BJT common-Emitter (CE) amplifier is shown in Figure Q4(b). Given: V_{CC}=18V, V_{BE}=0.7V, early voltage (V_A) =50V, R_1=47kΩ, R_2=8kΩ, R_C=4.7kΩ, R_E=2kΩ, R_S=500Ω, R_L =1kΩ and β=100.

(i) Draw the r_e model of the small-signal equivalent circuit of the amplifier. [4 marks]

(ii) Calculate V_B and I_E. [8 marks]

(iii) Determine βr_e and R_{in}. [5 marks]

(iv) Find the output resistance, r_o and the total AC load, R'_L. [4 marks]

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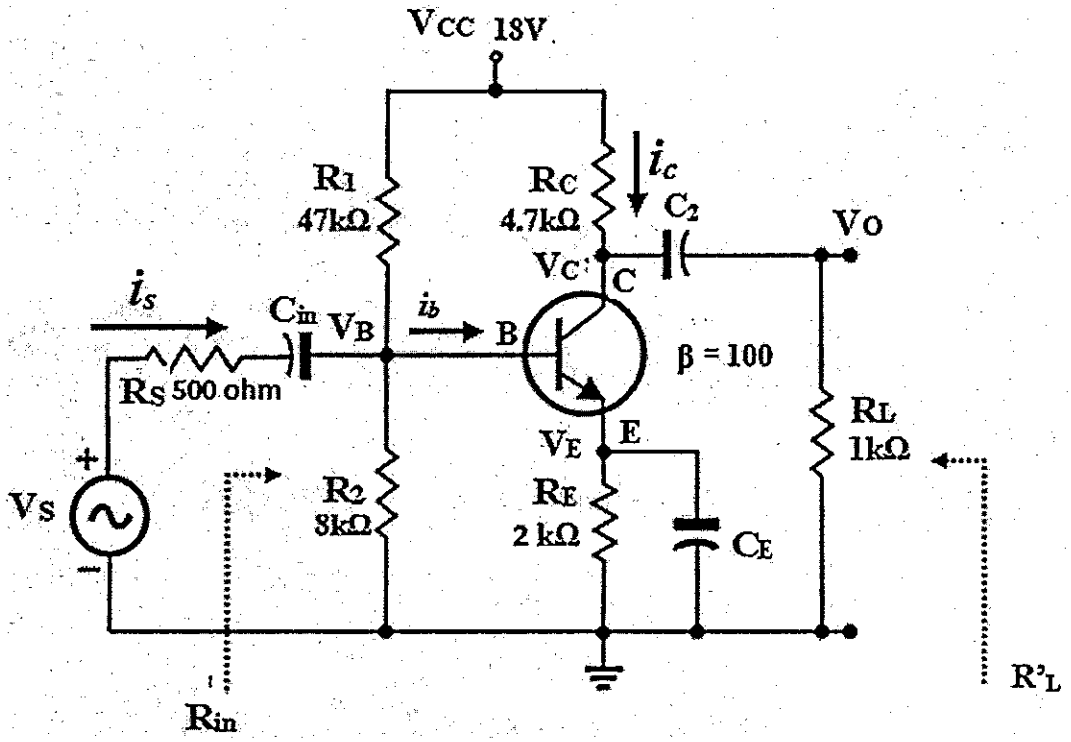

Figure Q4(b)

End of Question

APPENDIX

1. Charge of electron, $q = 1.6 \times 10^{-19}$ coulomb
2. Mass of electron, $m = 9.11 \times 10^{-31}$ kg
3. Holes and electrons in pure semiconductor, $p = n = n_i$
4. Law of Mass-action, $np = n_i^2$
5. Law of Electrical Neutrality, $\left(N_D^+ + p\right) = \left(N_A^- + n\right)$

   When all imprurities are ionised, $\left(N_D + p\right) = \left(N_A + n\right)$
6. In *n-type* semiconductor, $n_n \approx N_D$. In *p-type* semiconductor, $p_p \approx N_A$
7. Drift current density, $J_{drift} = J_n + J_p = \left(n\mu_n + p\mu_p\right)qE = \sigma E$
8. Characteristics of common semiconductors

Semiconductor	Intrinsic carriers/cm^3	μ_n (cm^2/V-s)	μ_p (cm^2/V-s)
GaAs	1.7×10^6	8500	400
Si	1.5×10^{10}	1350	410
Ge	2.5×10^{13}	3800	1800

9. Shockley diode equation, $i = I_o\left(e^{\left(\frac{V}{\eta V_T}\right)} - 1\right)$ where $V_T = \frac{kT}{q} = 26\text{mV}$
10. Form factor of rectifier, $FF = \frac{V_{o(rms)}}{V_{o(av)}}$
11. Ripple factor of rectifier, $\gamma = \sqrt{\left(\frac{V_{o(rms)}}{V_{o(av)}}\right)^2 - 1} = \sqrt{FF^2 - 1}$
12. RMS output voltage of half-wave rectifier, $V_{o(rms)} = \frac{V_{o(p)}}{2}$
13. RMS output voltage of full-wave rectifier, $V_{o(rms)} = \frac{V_{o(p)}}{\sqrt{2}}$
14. Average output voltage of half-wave rectifier, $V_{o(av)} = V_{o(dc)} = \frac{V_{o(p)}}{\pi}$

15. Average output voltage of full-wave rectifier, $V_{o(av)} = V_{o(dc)} = \frac{2V_{o(p)}}{\pi}$

16. Average output current of full-wave rectifier, $I_{o(av)} = I_{o(dc)} = \frac{2I_{o(p)}}{\pi} = \frac{2V_{o(p)}}{\pi R_L}$

17. Power dissipated at the load, $P_{(dc)} = I_{dc}^2 R_L$ and $P_{(rms)} = I_{rms}^2 R_L$

18. RMS output current of full-wave rectifier, $I_{o(rms)} = \frac{V_{o(rms)}}{R_L}$

19. Efficiency, $\eta_{\max} = \frac{P_{dc}}{P_{rms}}$

20. Internal emitter resistance of BJT, $r_e = \frac{V_T}{I_E} = \frac{26\text{mV}}{I_E}$

21. Internal output resistance of BJT, $r_o = \frac{V_A}{I_C}$

End of Paper